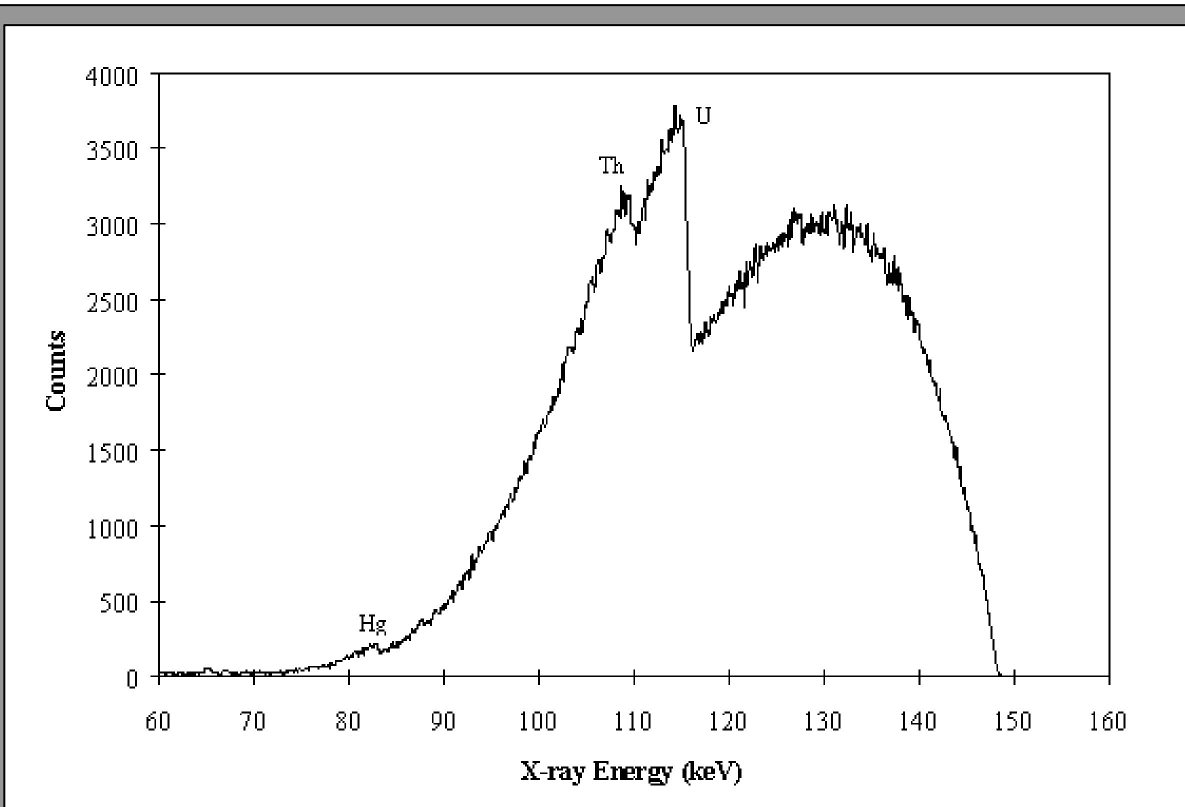
PORTABLE X-RAY, K-EDGE HEAVY METAL DETECTOR

TECHNOLOGY DESCRIPTION

A portable X-ray, K-edge heavy metal detector is being developed for the detection and quantification of hazardous metals contained within pipes, ducts, and equipment related to U.S. Department of Energy (DOE) deactivation and decommissioning efforts. The approach to this problem is based on observing the K-edge absorption transition in X-ray transmission measurements. The object to be inspected is located between an X-ray source and an energy-sensitive X-ray detector. The transmission spectrum is analyzed to determine the type and quantity of different elements present in the sample. Each element in the sample is identified by the unique energy at which the K-edge occurs. The amount of each element present is determined from the magnitude of the intensity change at the corresponding absorption edge. This method provides accurate quantification of heavy metals regardless of container material or geometry.



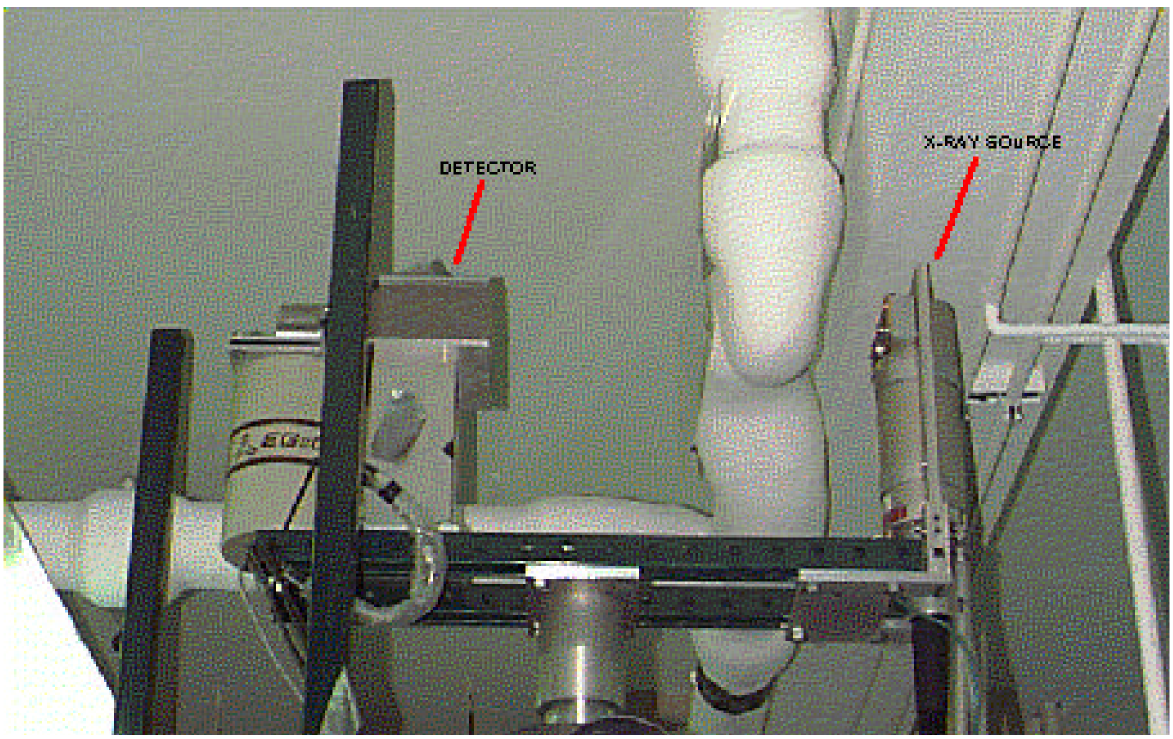
Example of a Spectrum Obtained During Inspection of Insulated Drain Lines Showing Mercury (Hg), Thorium (Th), and Uranium (U) Contamination

TECHNOLOGY NEED

Cleanup of many DOE facilities requires the dismantling of equipment that was used to process hazardous materials such as uranium, plutonium, and mercury. Examples include plutonium-processing glove boxes at the Los Alamos National Laboratory (LANL) and the Rocky Flats Environmental Technology Site (RFETS), and uranium processing facilities at the Oak Ridge National Laboratory

(ORNL) and the Savannah River Site (SRS). The K-edge technology was demonstrated at SRS in FY 1999 as part of the 321-M Large-Scale Demonstration and Deployment Project. Using existing techniques such as passive neutron and gamma measurements and neutron activation analysis, it is difficult and time consuming to detect and quantify these hazardous materials when they are contained within pipes, ducts, and equipment. Quantitative uncertainty can be ±100 percent in some cases. Rapid *in situ* analysis of these types of equipment for hazardous elements is needed to improve the efficiency and safety of deactivation and decommissioning efforts. Similar needs exist for characterization of mixed waste and spent nuclear fuel. In the DOE complex, there are more than 60,000 cubic meters of boxed waste that must be characterized and sorted for disposition. At the Idaho National Engineering and Environmental Laboratory (INEEL) there are 100 "odd lots" of spent fuel that are very difficult to characterize; similar problems arise at SRS where spent fuel from foreign research reactors is received for processing. Examples of applicable Site Technology Coordination Groups (STCG) need statements include:

- AL-07-01-11-MW - Waste Sorting and Characterization
- AL-07-02-06-MW - Characterization of Excess Legacy-Material Reactor Experiments
- ID-1.1.10 - Non-Destructive Determination of Fissile Material Content in Spent Nuclear Fuel
- ID-3.1.42 - Non-Destructive Assay for Resource Conservation and Recovery Act (RCRA) Metals in the Waste Experimental Reduction Facility (WERF) Incinerator Feed
- RL-DD05 – Characterization of Buildings 324 and 327
- RL-DD033 - Field Screening for Hazardous Materials for the 105-F and 105-DR Reactors
- RF-WM12 - Bulk Debris Characterization
- SR00-4005 - Characterization of Inaccessible Areas
- SR00-6008 – Technology for Assay of Dried Spent Nuclear Fuel



Sealed, insulated drainpipes were inspected for mercury, thorium, and uranium contamination using X-ray, K-edge technology. This demonstration was conducted at Wihelm Hall at Ames Laboratory in August 1998.

TECHNOLOGY BENEFITS

A fast, *in situ* method for quantifying the presence of uranium, plutonium, and Resource Conservation and Recovery Act (RCRA)-listed heavy metals inside closed containers greatly enhances the safety and efficiency of deactivation and decommissioning efforts. Accurate measurement of contaminants enables more efficient separation of materials, yielding significant savings in waste disposal. Accurate determination of the level and location of hazardous metals enhances the safety of dismantling operations.

The K-edge technology was demonstrated at SRS in FY 1999 as part of the 321-M Large-Scale Demonstration and Deployment Project. The results were compared against baseline nondestructive assay measurements. It was found that the production rate (feet of duct per hour) and cost (dollars per foot) were comparable for the two methods. However, the K-edge method provided greater detail on the location and nature of the holdup material. A detailed cost and performance analysis will be produced and presented in an Innovative Technology Summary Report (ITSR).

TECHNOLOGY CAPABILITIES/LIMITATIONS

K-edge densitometry can be used to quantify heavy elements ranging from cadmium to plutonium that are found in a range of matrix materials. The sensitivity achievable will depend on the specific combination of materials as well as on the data collection time. Typical precision of 10 percent for 10 mg/cm^2 of thorium, uranium, or plutonium in one inch of steel (100 ppm) is achievable within a few minutes. For lighter elements, such as lead or mercury in a matrix of aluminum or soil, sensitivity of 200 ppm can be obtained within a few minutes of measurement time. Greater sensitivity is possible with longer data collection times. Unlike passive non-destructive assay (NDA) techniques, K-edge analysis generally does not require correction for matrix effects. Little prior knowledge of sample composition or geometry is required.

K-edge densitometry requires access to both sides of a sample. The current state of technology for X-ray sources and detectors requires about one-foot clearance on either side of the sample. Special training for operation of the X-ray source is required, and personnel cannot work in the area around the inspection point during operation of the X-ray source.

The initial capital cost of the system will range from $80 to $150 K depending on the selection of the X-ray source and detector.

COLLABORATION/TECHNOLOGY TRANSFER

This project is currently being carried out at Ames Laboratory and Iowa State University, taking advantage of the existing expertise at the Center for Nondestructive Evaluation. The K-edge data acquisition and analysis software developed for this project is available for licensing.

ACCOMPLISHMENTS AND ONGOING WORK

- A prototype K-edge detector was assembled and tested in FY 1996.
- A K-edge data acquisition and analysis software package and Windows-based user interface program was developed, and is available for licensing.
- New algorithms were developed to handle cases of relatively thick contamination (greater than 1,000 mg/cm^2 of heavy metal), thus extending the range of applicability of K-edge analysis.

The prototype was successfully demonstrated at the Oak Ridge K-25 Site in February 1997. The Materials and Chemistry Laboratory hosted the demonstration and provided samples of one-inch inside diameter Monel pipes with uranium holdup to be inspected. Operation of the K-edge detector was demonstrated for uranium contamination ranging from 10 mg/cm^2 to 6,000 mg/cm^2 and the results from the K-edge measurements were found to agree with the baseline NDA measurements of passive gamma rays. The following report details the results of this demonstration:

- T. Jensen, T. Aljundi, C. Whitmore, H. Zhong, and J.N. Gray, “Field Demonstration of a Portable, X-Ray, K-Edge Heavy-Metal Detector,” Ames Laboratory Internal Report IS-5131, March 31, 1997.

From August 1997 to January 1998, a demonstration was carried out at the Iowa State University Nuclear Engineering Laboratory. Aluminum-clad uranium fuel plates were inspected to determine the feasibility of using K-edge analysis in determining the properties of spent nuclear fuel. This was in response to needs from the Idaho National Engineering and Environmental Laboratory (INEEL) and the SRS. The K-edge measurements agreed very well with predictions for uranium concentrations expected for stored spent nuclear fuel assemblies under a variety of matrix conditions. A representative of SRS visited Iowa State University in January 1998 and observed the operation of the K-edge detector. The following report details the results of this demonstration:

- T. Jensen, T. Aljundi, C. Whitmore, H. Zhong, and J.N. Gray, “X-Ray, K-Edge Measurement of Uranium Concentration in Reactor Fuel Plates,” Ames Laboratory Internal Report IS-5129, November 26, 1997.

In August 1998, a modified K-edge detector was demonstrated in the characterization of contamination in drain lines in Wilhelm Hall at Ames Laboratory. Sealed, insulated drainpipes were inspected for mercury, thorium, and uranium contamination. The following report details the results of this demonstration:

- T. Jensen and C. Whitmore, “X-Ray K-Edge Analysis of Drain Lines in Wilhelm Hall, Ames Laboratory,” Ames Laboratory Internal Report IS-5135, January 5, 1999.

In February 1999, the K-edge technology was demonstrated as part of the SRS 321-M Large-Scale Demonstration and Deployment Project. The holdup of highly enriched uranium in 84 feet of exhaust duct on the roof of the building was measured. The results were compared against baseline nondestructive assay measurements made with a sodium iodide detector. These results are being published in an Innovative Technology Summary Report, and also appear in the following conference proceedings:

- Terrence Jensen, Craig Whitmore, and Jeffrey W. Lee, “X-Ray K-Edge Measurement of HEU Holdup in the Savannah River Site 321-M Facility,” proceedings of the American Nuclear Society 2nd Topical Meeting on Decommissioning, Decontamination and Reutilization of Commercial and Government Facilities, September 12-16, 1999, Knoxville, TN.

TECHNICAL TASK PLAN/TECHNOLOGY MANAGEMENT SYSTEM INFORMATION

TTP No./Title: CH15C251 - Portable X-Ray, K-Edge Heavy Metal Detector
Tech ID/Title: 134 – Portable X-Ray, K-Edge Heavy Metal Detector

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The X-ray, K-edge inspection head is being positioned around a 20-inch-diameter duct at the Savannah River Site (SRS) 321-M Fuel Fabrication Facility. The X-ray tube is at the top of the arm, the high-purity germanium detector is to the left, and the imaging detector is to the right at the bottom of the arm.